

Partially Collapsible Structure

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1 TITLE OF THE INVENTION

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3 Partially collapsible structure
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6 BACKGROUND OF THE INVENTION
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8 This invention relates to the field of foldable sheet material, and more
9 particularly to a partially collapsible structure made from foldable sheet material.
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11 Several prior patents have addressed folded material in which the folds are of a
12 specific arrangement so that the material may be used in making articles for various
13 purposes. For example, U.S. Patent 4,780,344 to Hoberman discloses firm three-
14 dimensional expanded enclosures made from essentially two-dimensional collapsible
15 structures. U.S. Patent 4,981,732 to Hoberman discloses firm stable three-
16 dimensional expanded structures that can be collapsed down to compact bundles.
17 U.S. Patent 5,234,727 to Hoberman also discloses compacting larger structures.

18 U.S. Patent 4,049,855 to Cogan discloses a honeycomb type core configuration
19 for composite structural panels generated by folding sheet material. The box shaped
20 core, when attached to a surface sheet imparts rigidity to the sheet for use as a high
21 strength to weight ratio structural sheet panel. The cell walls of the folded core are
22 integral with the cell bottom, which provides a large surface area for ease of attachment
23 to the surface sheet.

24 None of these prior patents teach or suggest a partially collapsible structure as
25 is disclosed herein.

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3 BRIEF SUMMARY OF THE INVENTION
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5 It is an object of the present invention to provide a folding pattern for foldable
6 sheet material such that when folded, the sheet material provides structural integrity.

7 It is a further object of the present invention to provide a folding pattern for
8 foldable sheet material such that the sheet material when folded is partially collapsible,
9 yet also rigid.

10 It is also an object of the present invention to provide a set of folding operations
11 such that when sheet material is folded, a variety of partially collapsed structures
12 results.

13 In accordance with a preferred embodiment of the present invention, a partially
14 rigid and partially collapsible foldable sheet material having a longitudinal direction and
15 a transverse direction generally perpendicular to the longitudinal direction comprises at
16 least one longitudinal rigid strip that is partially rigid and partially collapsible in the
17 transverse direction and at least one alternating longitudinal collapsible strip that is
18 collapsible in the transverse direction; the longitudinal rigid strip is formed of generally
19 quadrilateral portions, each generally quadrilateral portion of the same rigid strip being
20 generally the same dimension in the transverse direction; the longitudinal collapsible
21 strip is formed of at least one quadrilateral-shaped portion.

22 Other objects and advantages will become apparent from the following
23 descriptions, taken in connection with the accompanying drawings, wherein, by way of
24 illustration and example, an embodiment of the present invention is disclosed.
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BRIEF DESCRIPTION OF THE SEVERAL DRAWINGS

The drawings constitute a part of this specification and include exemplary embodiments to the invention, which may be embodied in various forms. It is to be understood that in some instances various aspects of the invention may be shown exaggerated or enlarged to facilitate an understanding of the invention.

Figures 1A, 1B, 1C, and 1D are views in various stages of collapse of a partially collapsible structure in accordance with a preferred embodiment of the present invention.

Figures 2A, 2B, 2C, and 2D are views in various stages of collapse of a partially collapsible structure in accordance with an alternate embodiment of the present invention.

Figures 3A, 3B, 3C, and 3D are views in various stages of collapse of a partially collapsible structure in accordance with another alternate embodiment of the present invention.

Figures 4A, 4B, and 4C are views in two stages of collapse of a partially collapsible structure in accordance with another alternate embodiment of the present invention.

Figures 5A, 5B, and 5C are views in various stages of collapse of a partially collapsible structure in accordance with another alternate embodiment of the present invention.

Figures 6A, 6B, and 6C are views in various stages of collapse of a partially collapsible structure in accordance with another alternate embodiment of the present invention.

1 Figures 7A and 7B are views in two stages of collapse of a partially collapsible
2 structure in accordance with another alternate embodiment of the present invention.

3 Figure 8 is a perspective view of a partially collapsible structure in accordance
4 with another alternate embodiment of the present invention.

1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS
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3 Detailed descriptions of the preferred embodiments are provided herein. It is to
4 be understood, however, that the present invention may be embodied in various forms.
5 Various aspects of the invention may be inverted, or changed in reference to specific
6 part shape and detail, part location, or part composition. Therefore, specific details
7 disclosed herein are not to be interpreted as limiting, but rather as a basis for the
8 claims and as a representative basis for teaching one skilled in the art to employ the
9 present invention in virtually any appropriately detailed system, structure or manner.

10 Turning first to Figures 1A through 1D, there is shown a partially collapsible
11 foldable sheet structure in accordance with a preferred embodiment of the present
12 invention. One direction of sheet 21 is identified as the longitudinal direction, as is
13 shown by the arrows labeled L. The perpendicular direction of sheet 21 is labeled the
14 transverse direction and has identifying label and arrows T. It will be appreciated that
15 the longitudinal and transverse directions are for descriptions purposes only and that
16 there is no implication intended that one direction is longer than the other because of
17 the labels chosen.

18 Sheet 21 includes alternating rigid strips or sections 23 and collapsible strips or
19 sections 25. Each strip 23, 25 is oriented in the longitudinal direction and includes
20 sections along the strip. It will be appreciated that as shown in Figure 1, the rigid strips
21 23 and collapsible strips 25 are in a particular number, the invention is not so limited to
22 any particular number of rigid or collapsible strips 23, 25, respectively. It is important
23 that, in the transverse direction, one rigid strip 23 is followed, or preceded, by a
24 collapsible strip 25, there is no limitation to the total number of rigid strips 23 or
25 collapsible strips 25. The outer edges of sheet 21 are shown having phantom lines to

1 indicate the outer edge shape and particular number of rigid strips and collapsible
2 strips are not of significant importance to the present invention. For example, there
3 can be only one rigid strip 23 and only one collapsible strip 25. Alternately, there can
4 be only one rigid strip 23 with two collapsible strips 25, one on either side. Continuing,
5 there can be one collapsible strip 25 and two rigid strips 23, one on either side. It will
6 be appreciated that in all embodiments of the inventions described herein, these
7 alternate embodiments relating to the number of strips of collapsible and rigid strips is
8 applicable.

9 Further as shown in Figure 1A, sheet 21 is folded in a certain pattern. Sheet
10 folds in one direction are shown having solid lines, while sheet folds in the opposite
11 directions are shown in dashed lines in Figure 1A. This convention is maintained in the
12 illustration of the flat sheet of each embodiment throughout the description of the
13 invention, regardless of the embodiment described.

14 As is evident from Figure 1A, longitudinal rigid strips 23 are formed by a series
15 of quadrilateral portions 27. In the embodiment shown, each quadrilateral portion 27 is
16 a square, though it will be appreciated that the quadrilateral portions 27 may also be of
17 rectangles that are not squares, or parallelograms and still keep within the intentions of
18 the present invention. Further, though shown having a specific number of quadrilateral
19 portions 27 in Figure 1, there is no such limitation in accordance with the present
20 invention. The number of quadrilateral portions 27 within each longitudinal rigid strip
21 23 is of no consequence to the invention, and may be designed in accordance with a
22 particular application of the invention. This is the case regardless of the particular
23 embodiment being described throughout.
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1 It is also appreciated from Figure 1A, each quadrilateral portion 27 within a
2 particular longitudinal strip 23 has substantially the same transverse dimension. This is
3 the case regardless of the particular embodiment being described throughout.

4 In addition, though it is apparent from Figure 1 that sheet 21 has regular,
5 straight edges on all sides, the shape of the edges are of no consequence to the
6 present invention, and may be of any shape as is necessary for the particular
7 application of the invention. This is the case regardless of the particular embodiment
8 being described throughout.

9 Further, as is evident from Figure 1A, each longitudinal collapsible strip 25 is a
10 mirror image of it's nearest or closest longitudinal collapsible strip 25, such is not
11 necessitated by the present invention, as will be seen in alternate embodiments
12 discussed below.

13 Continuing with Figure 1A, each longitudinal collapsible strip 25 is formed by a
14 series of quadrilateral portions 29. Although in Figure 1, there is shown a specific
15 number of quadrilateral portions 29 in Figure 1, there is no such limitation in
16 accordance with the present invention. The number of quadrilateral portions 29 within
17 each longitudinal collapsible strip 25 is of no consequence to the invention, and may be
18 designed in accordance with a particular application of the invention. This is the case
19 regardless of the particular embodiment being described throughout.

20 Turning now to figures 1B and 1C, it is evident that, because of the folding
21 pattern of the alternate longitudinal rigid strips 23 and longitudinal collapsible strips 25,
22 as sheet 21 is folded and compressed in the transverse direction, collapsible strips 25
23 fold such that some of one surface portion 29 touches some of adjacent surface portion
24 29. In contrast, when folded, none of one portion 27 of longitudinal rigid strip 23
25 touches any of adjacent portion 27. It is appreciated that when compressed in the

1 transverse direction, longitudinal rigid strips 23 provide transverse structural rigidity,
2 while longitudinal collapsible strips 25 provide the overall collapsed shape of sheet 21,
3 as viewed from the longitudinal cross section perspective.

4 This is evident in more detail from inspection of Figure 1D wherein is shown a
5 collapsed longitudinal collapsible strip 25. Each longitudinal collapsible strip 25 defines
6 two surfaces, one top sided and the other bottom sided. In addition, each longitudinal
7 collapsible strip 25 defines two edges. It is at the surface that the longitudinal
8 collapsible strip 25 collapses and at the edges where the longitudinal collapsible strip
9 25 joins a longitudinal rigid strip 23. In the embodiment illustrated in Figures 1A
10 through 1D, only one edge of collapsible strip 25 is visible when collapsible strip is
11 folded in the fully compressed form and viewed from one side or the other side. As is
12 evident from inspection of alternate embodiments herein described, one edge of
13 longitudinal collapsible strip 25 will always be visible when collapsible strip is fully
14 compressed, though portions of the opposite edge may also be visible. This is the
15 case regardless of the particular embodiment being described throughout.

16 It will be appreciated that when sheet 21 is in the fully folded and transversely
17 compressed configuration compression in the longitudinal direction also occurs. When
18 so compressed, the surfaces of longitudinal collapsible strip 25 may be fixed together
19 in a variety of ways including using a variety of glues or staples or otherwise so that
20 sheet 21 may retain the collapsed rigid structure. It will also be appreciated that the
21 surfaces of longitudinal collapsible strip 25 may not need to be fixed. For example,
22 sheet 21 may be inserted in a box or other structure that will in effect maintain the
23 transverse pressure on sheet 21 thereby maintaining sheet 21 in the compressed
24 configuration. In this example, sheet 21, when removed from the box, may be
25

1 expanded to the state shown in, for example Figure 1A or Figure 1B. This is the case
2 regardless of the particular embodiment being described throughout.

3 Further, depending upon the embodiment, when folded, each sheet 21 may be
4 nested one on top of the other, as is shown in Figure 1D in phantom lines.

5 Turning now to Figures 2A through 2D, where similar elements will be identified
6 with similar numbers, there is shown an alternate embodiment of the present invention.
7 Specifically, longitudinal collapsible sheet 21' is having longitudinal rigid strip 23' of a
8 series of varying quadrilateral portions 27', each able to have a different parallelogram
9 shape. In addition, longitudinal collapsible strip 25' is from a series of quadrilaterals,
10 though not necessarily parallelograms. As is shown in Figures 2B and 2C, once folded
11 and compressed in the transverse direction, the cross-sectional shape can be varied
12 significantly. The particular folding pattern of longitudinally collapsible strip 25' is
13 shown in Figure 2D

14 Turning now to Figures 3A though 3D, there is shown an alternate embodiment
15 of the foldable sheet in accordance with the present invention. Figure 3A illustrates the
16 folding pattern on sheet 21''. There is shown the alternating longitudinal collapsible
17 strip 25'' and longitudinal rigid strip 23''. Longitudinal rigid strip 23'' includes a series of
18 rigid portions 27'' in parallelogram shape, specifically rectangles. Particular attention is
19 drawn to longitudinal collapsible strips 25'' formed of a series of folds defining both
20 quadrilaterals and triangles. This series of folds, when compressed in the transverse
21 direction, create a structure as shown in Figures 3B and 3C and has the longitudinal
22 collapsible strip 25'' profile as shown in Figure 3D. Longitudinal collapsible strip 25'' is
23 formed from a pattern of folding lines that define a series of geometric shapes, and in
24 the illustrated embodiment these shapes include triangles and quadrilaterals. From
25 inspection of Figure 3A it is immediately apparent that the folding pattern of the

1 longitudinal collapsible strip at no point defines a series of three successive triangles
2 two of which are right isosceles triangles equal in area and bordering a third right
3 isosceles triangle twice the area of either the other two. It will be appreciated that by
4 varying the dimensions of the folds within the longitudinal collapsible strip 25" and the
5 longitudinal rigid strip 23", a variety of box-like structures may be formed when sheet
6 21" is in the compressed, folded formation.

7 Turning next to Figures 4A and 4B, there is shown an alternate embodiment of
8 the present invention. Specifically, there is shown within longitudinal rigid strips 23"
9 cut-away material 31, such that when transversely compressed there exists a removed
10 portion 32 in which an object 33 can be placed, for example, shipping the object and
11 providing protection during shipping. It will be appreciated that a variety of designs of
12 cut-away material 31 may be employed for any desired application. For example, in
13 Figure 4A, cut-away material 31, at times crosses between one quadrilateral portion
14 27" of longitudinal rigid strip 23", but is not necessary for the present invention. Cut-
15 away material may be in any portion of rigid strip 23" as is needed for the particular
16 application. In addition, and although not shown, cut-away material 31 may be within
17 longitudinal collapsible strip 25" and may be within a particular quadrilateral portion or
18 may cut across more than one quadrilateral portion with longitudinal collapsible strip
19 25". Further, cut-away material 31 may span one or more quadrilateral portions
20 between longitudinal collapsible strip 25" and longitudinal rigid strip 23", or any
21 combination of the above described embodiments. Figure 4B illustrates the sheet of
22 Figure 4A when folded, while Figure 4C illustrates two folded sheets such as that
23 shown in Figure 4A and further showing a structure that may be fit between the two
24 folded sheets as crated by the cut-away material.

1 Turning next to Figures 5A through 5C there is shown an alternate embodiment
2 of the present invention wherein longitudinal rigid strip 25''' is formed of a series of
3 quadrilateral portions 29''', not rectangles. As is clear from Figures 5B and 5C, when
4 transversely compressed in the folded formation, a structure is formed as shown.
5 Longitudinal rigid strip 23''' is partially collapsed in the transverse direction due to the
6 folding pattern. Indeed, in all embodiments, the longitudinal rigid strip is partially
7 collapsible, though in many of the above-described embodiments, the part collapsible
8 is nothing. As is clear from the illustrated embodiments, each longitudinal strip,
9 whether collapsible or rigid, is formed having parallel edges. It is the angle between
10 the parallel edges and the edges of the parallelograms that form the quadrilateral
11 portions within each longitudinal rigid strip that determine the degree to which the
12 longitudinal rigid strip is collapsible. This is the case regardless of the particular
13 embodiment being described throughout. Accordingly, the term rigid as used herein is
14 to refer to the portion that is not entirely collapsible when the sheet is folded and fully
15 compressed, rather than limiting the rigid strip to any degree of collapsibility.

16 Turning now to Figures 6A through 6C, there is shown an alternate embodiment
17 of the present invention. Folding pattern illustrated in Figure 6A results, when fully
18 folded and compressed in the 3-dimensional checkerboard structure shown in Figure
19 6B. Longitudinal collapsible strip, when folded is shown from a side view in Figure 6C.
20 As is evident from inspection of Figure 6A, in this particular embodiment, the
21 designation between the longitudinal direction and the transverse direction may be
22 interchanged without consequence. Important to the invention, longitudinal collapsible
23 strip is formed from a pattern of folding lines that define a series of geometric shapes,
24 and in the illustrated embodiment, these shapes include triangles and quadrilaterals.
25 From inspection of Figure 6A it is immediately apparent that the folding pattern of the

1 longitudinal collapsible strip at no point defines a series of three successive triangles
2 two of which are right isosceles triangles equal in area and bordering a third right
3 isosceles triangle twice the area of either the other two.

4 As an alternate example of a foldable sheet in accordance with the present
5 invention, Figures 7A and 7B illustrate an alternate design, though the invention is not
6 intended to be limited to the particular embodiments shown.

7 In addition, as is illustrated in Figure 8, the foldable structure, once transversely
8 compresses may be laminated on the top side. Though not illustrated, bottom side
9 lamination is also in accordance with the present invention, as is lamination from the
10 top and bottom side in the same structure. The laminating material may be of any
11 appropriate type including, without limitation, paper, cardboard, metal, plastic, etc.

12 It will be appreciated that sheet 21 may be of any foldable material as is
13 appropriate for a desired application. For example, sheet 21 may be metal, paper,
14 plastic, cardboard, a composite material, etc.

15 While the invention has been described in connection with preferred
16 embodiments, it is not intended to limit the scope of the invention to the particular
17 forms set forth, but on the contrary, it is intended to cover such alternatives,
18 modifications, and equivalents as may be included within the spirit and scope of the
19 invention as defined by the appended claims.

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